Sierra Nevada Network
Vital Signs Monitoring Plan

Appendix H: Protocol Development Summaries

Natural Resource Report NPS/SIEN/NRR—2008/072

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Birds

Justification

Increasingly, birds are seen as appropriate indicator species of local and regional change in terrestrial ecosystems. The Sierra Nevada Network parks—Sequoia and Kings Canyon National Parks (SEKI), Yosemite National Park (YOSE), and Devils Postpile National Monument (DEPO)—together provide over 1,600,000 acres of habitat for over 200 species of birds, including many neotropical migrants. Critical breeding, stopover, and wintering grounds occur from lands adjacent to the parks and monument to land as far south as Patagonia. SEKI, YOSE, and a few other large habitat areas in the Sierra Nevada have been designated by the American Bird Conservancy as Globally Important Bird Areas (IBA). Analysis of North American Breeding Bird Survey data indicates that numerous bird species exhibit declining long-term population trends in the Sierra Nevada region.

Bird Monitoring is the only Sierra Nevada Network (SIEN) vital sign that would monitor multiple species across the entire elevational gradient.

Background Information

Researchers have identified eight potential Sierra-wide risks faced by Sierra Nevada birds: livestock grazing, logging, fire suppression, exurban development, increased recreational use, pesticide use, habitat destruction and degradation on wintering grounds, and large-scale climate change (DeSante 1995; Graber 1996). Data from the MAPS (Monitoring Avian Productivity and Survivorship) program suggest that populations of numerous species are declining in Yosemite, and that the majority of those declines appear to be tied to low productivity (presumably resulting from factors occurring in the park where breeding habitat is found), rather than low survival on wintering grounds (DeSante et al. 2005). Birds generally occupy a high position on the food web, and they provide important ecological functions such as seed dispersal and insect predation, making them good indicators of change in ecosystems.

Because of their high body temperature, rapid metabolism, and high ecological position on most food webs, birds are excellent indicators of the effects of local, regional, and global environmental change on terrestrial ecosystems. Furthermore, their abundance and diversity in virtually all terrestrial habitats, diurnal nature, discrete reproductive seasonality, and intermediate longevity facilitate the monitoring of their population and demographic parameters (DeSante et al. 2005).

Bird populations provide an attractive vital sign and provide the opportunity for detailed evaluation of network ecosystem condition because birds (1) occupy a wide diversity of ecological niches in the parks and (2) are conspicuous and easily observable.

In addition, (1) knowledge of the natural history of many bird species has a rich basis in literature, (2) all units in SIEN have a strong foundation of inventory data upon which to build future monitoring efforts, and (3) monitoring of avian productivity and survivorship has occurred at all parks for varying numbers of years and time periods. Monitoring Avian Productivity and Survivorship (MAPS) programs have been operating in Sierra Nevada Parks for many years, and at one station in Yosemite for 17 years.

Forest birds throughout the Sierra Nevada face numerous potential stressors and changes, including pollution and pesticide up-drift from the Central Valley, increasing exurban development (Duane 1999) with its concomitant increases in land conversion, habitat fragmentation, facilitation of Brown-headed Cowbird parasitism, and long-term shifts in habitat composition and structure resulting from fire exclusion (Helj 1994; Chang 1996; Gruell 2001), projected climate change (Lenihan et al. 2003, Hayhoe et al. 2004), and recent decisions by the USDA Forest Service to increase timber harvest and forest thinning efforts to reduce fuels.

Specific Monitoring Questions and Objectives

Monitoring Objectives

Our bird monitoring protocol addresses three of eleven broad monitoring objectives eveloped for the Network's long-term monitoring program:

1. Document rates and types of change in animal communities in response to changes in landscape characteristics, biotic interactions, and human use
2. Understand the ecological relationships between terrestrial landscape elements and animal distributions
3. Monitor trends in the distribution and abundance of focal species

Monitoring Questions

The Sierra Nevada Network Bird Workgroup established broad monitoring questions at its first meeting in FY2006. However, after continued investigation of other Network approaches and experiences (discussed below, Protocol Development & Status), the workgroup realizes that Network-wide and park-level inference may not be feasible because the parks are so large—their size presents logistical issues and financial challenges associated with sampling remote locations (excepting Devils Postpile). Further, because of the topographic complexity of our parks, it may be necessary and efficient to focus on specific bird habitats (e.g., foothill oak woodland, subalpine meadow, white fir forest, riparian) or species thought most affected by the stressors affecting Network parks. Monitoring questions were refined during early 2007, as follows:

1. Detect trends in the density of those landbird species monitored well by point counts, throughout accessible areas of SIEN parks during the breeding season
2. Track changes in breeding-season distribution of landbird species throughout accessible areas of SIEN parks.

Potential Measures

Density, relative abundance, diversity as a function of habitat type, and, possibly, productivity & survivorship, in limited locations.

Basic Approach

In FY2004-2005, before a formal Bird Workgroup was established, the Sierra Nevada Network contracted with The Institute for Bird Populations (IBP) to make general recommendations for avian monitoring sample design alternatives for monitoring (1) trends at the landscape level, and (2) trends in subalpine meadows (Siegel and Wilkerson 2005). Data from avian inventories, Monitoring Productivity and Survivorship (MAPS), and Breeding Bird Surveys were used to provide a preliminary assessment of power to detect population trends using a landscape-level monitoring program, and an assessment using meadow monitoring. In addition, Breeding Bird Survey data were used to assess which habitats are under-sampled by existing Sierra Nevada-wide bird monitoring efforts. Preliminary implementation budgets were also provided.

In FY2006, the network established a formal Bird Workgroup (comprising park and network staff) to establish broad avian monitoring objectives. In addition, a contract was established with IBP to facilitate decision-making and develop SIEN's bird monitoring protocol. In January 2007, the workgroup met (with IBP and several additional outside experts with experience monitoring birds in the Sierra) to refine monitoring objectives, devise an approach to protocol development, and–in light of the previous two decisions–determine feasibility and value of continuing the collection MAPS data.

Protocol Development & Status

The Institute for Bird Populations will apply its extensive experience developing and refining a bird monitoring protocol for the North Coast Cascades Network (NCCN).

Tentative Sampling Methods & Design

The SIEN bird monitoring protocol will follow that of NCCN, and will therefore consist of Variable Circular Plot (VCP) (Siegel et al. 2007) methodology at points along transects (spatial) at the three large park units of SIEN, including an array or riparian design at DEPO. Numerous discussions of the costs and benefits of different types of bird monitoring programs (e.g., MAPS versus VCP), conducted elsewhere, was again recapped at this meeting (in addition to discussions over the past several years), and the group feels confident that the above-method will best achieve SIENs monitoring objectives. Reasoning: the current predicted 70% change in snowpack will cause significant change in habitats, which argues for a spatial design (i.e., VCP).

The Bird Workgroup decided to include an explicit statement in the monitoring protocol to include MAPS monitoring—as an important component of a comprehensive SIEN bird monitoring protocol—while noting (and understanding) that it is currently an unfunded part of bird monitoring in SIEN. Members of the Bird Workgroup are committed to finding additional funding to continue the MAPS program in SIEN.

NCCN and Terrastat Consulting performed power analyses and found the following: 4% per annual change in a park is detectable after 15-20 yrs for 20+ species (Siegel et al. 2007). IBP is confident that SIEN data would meet or exceed this power. Because of this, the Bird Workgroup decided that power analyses of our current data (inventory) are unnecessary; instead, power analysis of the data would be conducted after five years of SIEN data (monitoring) had been collected.

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Schedule (protocol development)

April 2006	Define broad bird monitoring objectives
July 2006	Establish contract with Institute for Bird Populations (IBP)
Winter 2006-2007	IBP facilitates workgroup refinement of monitoring and sampling objectives
April 2007	Database development (review/modify NCCN for SIEN)
April 2007	IBP begins drafting of Bird Monitoring Protocol
June 2007	Draft sample design complete
September 2007	Draft protocol complete (for YOSE & SEKI)
September 2007	Meet with PI to discuss sample design for DEPO
January 2008	Final protocol to peer review

Budget*

$24,800	Contract with IBP (Tasks 1-4, above)
$5,000	Statistical assistance (U of Idaho Cooperative Agreement)
$15,500	In-kind Park Staff Time

**No additional funds for protocol testing or implementation are available, at the current time (Spring 2007).*

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Protocol: Early Detection of Invasive Plants

Parks Where Protocol will be Implemented

Devils Postpile National Monument (DEPO)
Sequoia & Kings Canyon (SEKI)
Yosemite National Parks (YOSE)

Vital Signs Addressed by Protocol

Non-native Invasive Plants

Justifications/Issues being addressed

Invasive non-native plants can bring about significant changes in park ecosystems by changing structural attributes of native plant communities (physiognomy, species composition, genetic diversity) and the processes that support them (fire, nutrient cycling, hydrology, soil erosion, decomposition) (MacDonald et al. 1988). There are over 200 non-native plant taxa in Sierra Nevada Network (SIEN) parks, and new introductions continue to occur. Many of these taxa are invasive, or a threat to native plant and animal communities—they compete for space and resources, and often do not meet the same habitat needs of animals as do native plants.

The Network hosted a workshop focused on developing and prioritizing monitoring objectives for invasive non-native plants in May 2005, and the primary monitoring interests identified for the Inventory and Monitoring program involved early detection and trends monitoring. The first protocol we will develop is early detection monitoring. Vast areas of the network parks are free of invasive plants, and all parks' highest invasive plant management priorities are to prevent new introductions to these weed-free areas, to detect new introductions early in the invasion process, and to provide rapid eradication response. By definition, early detection monitoring focuses on locating spatially rare events, so standard sampling procedures may not be effective. To narrow the search frame and be most effective with limited funds, others have narrowed the list of target species for searching, modeled the highest potential habitat for target species, modeled the highest probability areas for new introductions based on invasion vectors or plant community characteristics, or used adaptive sampling. To assist park managers and Inventory and Monitoring staff with this complex problem, regional NPS staff and the USGS are collaborating to develop an early detection handbook.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol

Monitoring Questions

1. What non-native species are present in the parks and how do these species change over time?
2. What non-native species not currently present in the parks most threaten native ecosystems?
3. What are the priority non-native species for early detection monitoring based on ecological impacts, invasiveness potential, and distribution?
4. Are new species, or new populations of species already present in the parks, establishing in weed-free areas, high-value resource areas, or naturally-disturbed areas?

Monitoring Objectives

1. Periodically review park weed management databases and update NPSpecies with new taxa not yet vouchered and documented. From NPSpecies, update each park's non-native species list, using a defined set of criteria for inclusion, and evaluate changes.
2. Create and periodically update a "watch list" of species that are not present in the parks but are known to exist in the region or to have the potential to become problematic in the region.
3. Create and periodically update early detection monitoring priorities for species in lists one and two using a transparent, documented system.

4A. Compile and periodically update polygons of weed-free areas, high-value resources areas, and naturally-disturbed areas, from a defined set of criteria, using existing information.

4B. Within the polygons defined in Objective 4A, detect (1) watch-list species, and (2) new populations of priority species already present in the parks through either (a) complete search/census, or (b) sampling within search frames narrowed by selection criteria based on vectors, environmental factors, and other susceptibility measures.

4C. Expand scope of personnel searching for watch-list species by developing SOPs and training materials to be included in other I&M protocols, in wilderness ranger duties, and in other park staff and volunteer efforts as appropriate.

Basic Approach

Comprehensive early detection protocols will be developed following the publication of the NPS/USGS "Early Detection of Invasive Plant Species Handbook," anticipated in 2007/2008. In the meantime, SOPs for Objectives 1, 2 have been developed; Objective 3 will begin in the Fall-Spring of 2007-2008 (these are not likely to change with the publication of the Early Detection Handbook). These products will move us closer to full development of early detection protocols and will be helpful to management in the interim.

Objective 1: Create criteria and SOPs by which each park's non-native plant species list will be periodically updated from NPSpecies. For example, a park may have 160 non-native species if the vouchered, naturalized species list is extracted from NPSpecies. However, if waifs, cultivars, landscape plantings, extirpated species, un-vouchered observations, or specimens keyed to genus are included, a park may have many more non-native taxa. A non-native plant species list is very dynamic, and the criteria used to extract the list and track changes needs to be defined. In addition, invasive plant crews may identify new species but not collect a voucher specimen, or collected vouchers may languish in an office without being verified and added to NPSpecies. A periodic effort to collect voucher specimens, verify plant identifications, and add to NPSpecies are part of this protocol.

Objective 2: Create SOPs to produce and periodically update a "watch list" of species that are not present in the parks but are known to exist in the region or to have the potential to become problematic in the region. We will research how other parks have created watch lists, modify their SOPs if appropriate, speak with adjacent land managers, and search priority species lists for surrounding regions. An updated (2008 and beyond) watch list will be created based on this SOP.

Assessment Protocol to Prioritize Non-native Plant Species for Early Detection and Rapid Response.

The majority of questions that make up our assessment criteria have been drawn from natureserve's invasive species assessment protocol (Morse, Randall et al. 2004). Morse and colleagues suggested that a combination of high ecological impact, low current distribution, and high potential distribution, should indicate a high priority for early detection.

We have expanded on this basic premise in order to derive the early-detection ranks. Our protocol is in the form of a database, and was designed to leverage existing vegetation data from SIEN parks. To assess a species of interest, the database synthesizes information from published sources and datasets. The database also provides a means to update a suite of species periodically.

We have also developed a protocol to develop and update watchlists of species that have not yet invaded these parks, but have the potential to do so. The criteria are based on the proximity and similarity of habitats of current infestations, and their tendency to be invasive in natural ecosystems.

For *Objective 3*, we will create SOPs to produce and periodically update a prioritization for early detection of species in lists one and two. Published species prioritization systems such as Hiebert and Stubbendieck's Alien Plants Ranking System (APRS 2000), NatureServe/TNC's Invasive Species

Assessment Protocol (Morse, Randall et al. 2004), or the California Invasive Plant Inventory (Warner, Bossard et al. 2003), will be reviewed, compared, and one chosen and modified. Species prioritizations for early detection monitoring may be different from (and use different criteria than) species prioritizations for management. The result will be a list of target species for early detection monitoring that will include two classes of target species: (1) new populations of species already present in the parks, (2) species new to the parks (i.e., "watch list" species). A 2006 or 2007 prioritization will be created based on this SOP.

Projects Conducted in Support of Early Detection and Protocol Development

We commissioned a report describing the procedures for the development of a sampling protocol for inventorying alien plant species in wildfire and riparian areas (in Yosemite National Park). The inventory has two purposes: (1) to provide data for an analysis of general patterns of distribution and abundance of alien species in wildfire and riparian areas, and (2) to create a baseline dataset to compare future surveys with (i.e., monitoring). It was the initial step in developing a formal monitoring protocol for alien speices in wildfire and riparian areas.(Klinger and Underwood 2002; Underwood, Klinger et al. 2004). Subsequent to the underlying theme of this report, we undertook the following two projects.

In 2005, we supported an inventory project for invasive non-native plants in riparian habitat within Yosemite. This project will refine knowledge of vegetation conditions—specifically alien invasive plant species presence—in areas subject to natural disturbance, specifically riparian habitat. The final report include correlation analyses (for all pertinent physical, biological, and environmental variables (Kane, Heath et al. 2006). Results will provide a baseline against which changes in distribution and abundance of selected species could be measured and will assist vegetation management staff with prioritization of individual populations and sites for control or eradication efforts.

In 2006, we supported pilot monitoring efforts already underway in SEKI and YOSE related to early detection of invasive plants in burned areas, a subset of Objective 4. In YOSE, Kristin Kaczynski and Dr. Susan Beatty of University of Colorado at Boulder and in SEKI, Nate Bensen and Jeff Morisette of NASA Goddard Space Flight Center are working on projects to narrow the search frame within burned areas to successfully and efficiently detect target non-native plants after fire.

The objectives of the Kaczynski and Beatty project in YOSE are to determine:

1. If there is a relationship between fire severity and the density, frequency, and percent cover of invasive species in wilderness areas of Yosemite National Park
2. If remote sensing is a feasible option for early detection of invasive plants after fire in remote locations (e.g., National Park wilderness)

The result will be a predictive evaluation/ model of the probability of encountering an invasive plant population based on fire severity and habitat characteristics, and a evaluation of the feasibility of using remote sensing for early detection in Sierra burned areas (Kaczynski 2007).

The report from NASA Goddard is pending completion of the project.

Non-native Plants

Sample designs for non native plant monitoring will be geared towards early detection. We will review and implement, where possible, results of the publication of the NPS/USGS "Early Detection of Invasive Plant Species Handbook," anticipated in 2007.

In the meantime, SIEN is developing products necessary to fulfill development of early detection monitoring protocols and to conduct Handbook recommendations: (1) periodic update of each park's non non-native plant species list, (2) a scheme for prioritization for early detection of specific species on SIEN park lists (above), (3) creation of a "watch list" of species not currently present in the parks but known to exist in the region or to have the potential to become problematic in the region, and (4) continued support for two monitoring projects already underway in SEKI and YOSE related to early detection of invasive plants in burned areas (these projects are being conducted by cooperators at University of Colorado and NASA Goddard Space Flight Center).

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Cooperators

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NASA Goddard Space Flight Center

University of Colorado, Fort Collins

Bradshaw Consulting

PRBO Conservation Science, Point Reyes, CA

Additional cooperators in protocol development: to be identified in 2007.

Development Schedule, Budget, and Expected Interim Products

2005

Riparian PRBO

2006

- Review early detection literature (internal)
- Develop SOPs for Objectives 1 (internal)
- Develop SOPs for Objectives 2 and 3 and implement SOPs

  a) Contract with Ginger Bradshaw Kelleher ($20,000)
- Pilot early detection strategies in burned areas

  b) Support Kaczynski and Beatty study in YOSE on detecting invasive plants after fire

  c) Support NASA pilot project in SEKI on a support system for NPS decisions on fire management activities and invasive plant species control

2007

- Create SOP for objectives 4A and 4C – funds obligated in FY2006.
- Write protocol narrative, background, and objectives
- Identify cooperator for developing sampling design and field methods
- Cost: $20,260

*2008

Following publication of NPS & USGS Early Detection Handbook:

- Develop sampling design
- Develop field methods
- Develop data management protocols
- Develop analysis and reporting protocols
- Draft protocol for internal review
- Estimated Cost: $40,000

*2009

Final protocol for peer review

**Funds to fully develop this protocol may not be available as it received low priority by the Board of Directors in FY2007. At this time, we will only be able to develop a few Non-native Plant Early Detection SOPs to implement as part of other protocols and as part of our data management program.*

Kaczynski, K. 2007. Invasive species in Wilderness as a function of burn severity: A case study in Yosemite National Park, California. University of Colorado, Boulder, CO. MS Thesis.

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Protocol: Forest Dynamics

Parks Where Protocol Will be Implemented

Sequoia & Kings Canyon (SEKI)
Yosemite (YOSE)
Devils Postpile (DEPO)—perhaps, depending on species monitored

Vital Signs Addressed by Protocol

Forest Population Dynamics

Justification/Issues Being Addressed

Sierra Nevada montane and subalpine coniferous forests comprise one of the largest and most economically important vegetation regions in California (Rundel, Parsons et al. 1988). They are very complex in composition, structure and function (Franklin and Fites-Kaufmann 1996). We are most interested in monitoring forest dynamics, i.e., birth, growth and death rates of trees, because they are sensitive to changes in the two major drivers in the Sierra Nevada–climate and fire regimes. These two drivers are subject to substantial alteration by human impacts, and in these altered states can act as stressors on forest systems.

Background Information

Recent research results suggest that forest dynamics may already be showing effects of climatic changes. Forest turnover rates (defined as the average of tree mortality and recruitment rates) have been increasing in tropical Amazonia (Phillips et al. 2004) and in the Sierra Nevada (Stephenson and van Mantgem 2005). In the Sierra Nevada, a possible cause for this more rapid forest turnover rate is that summers have been getting warmer and drier. Snowpack has been decreasing over most of the West in recent decades (Mote et al. 2005) and spring stream flow has been occurring earlier (Stewart et al. 2004).

A variety of studies suggest that past Sierra mixed conifer forests had lower tree density and very different demographic distribution of age classes—with lower fuel loads and greater landscape diversity of forest patches than current forests (Vankat and Major 1978; Parsons and DeBenedetti 1979; Bonnicksen and Stone 1982; Vale 1987; Ansley and Battles 1998; Roy and Vankat 1999; Stephenson 1999). While many of the changes observed in forest structure and function are thought to be primarily due to fire exclusion, they may also be related to warmer, moister conditions of the 20th century (Graumlich 1993; Scuderi 1993; Keeley and Stephenson 2000).

Simulation models of climate change suggest that predicted warmer temperatures will alter water availability due to changes in type of precipitation and timing of snowmelt in the Sierra Nevada (Knowles and Cayan 2001; Dettinger et al. 2004). In addition to direct effects of reduced moisture availability and higher temperatures on forest dynamics, climatic change will also interact strongly with other stresses affecting forests. These include such things as: air pollution (e.g., N deposition, increasing atmospheric CO^2), non-native invasive species (including pathogens), land-use change (including habitat fragmentation), and altered fire regimes.

While there are other aspects of forest vegetation we will consider monitoring (e.g., lichen communities), we focus primarily on forest tree population dynamics because:

1. There is a successful track record of doing this kind of work already in these parks and a wealth of baseline data to build upon (USGS Global Change Research Program, NPS Fire Effects program).
2. Forest tree population dynamics data are interpretable and changes are often closely tied to drivers and/or stressors whose effects we seek to better understand (fire, climate, pollution and non-native species).
3. Trees comprise a keystone life form, creating the array of microclimates and habitats that entrain other ecosystem components and processes (such as wildlife and hydrology).

Additionally, USGS Research Ecologist Nate Stephenson makes these points regarding the importance of monitoring forest dynamics:

- Forests provide humans with irreplaceable resources and services.
- Climatic change will profoundly affect forests.
- Forests may profoundly affect climatic change (because they sequester the majority of the terrestrial biosphere's carbon, affect surface albedo and the hydrologic cycle, etc).

Specific Monitoring Questions and Objectives

The Sierra Nevada Network identified a set of broad monitoring objectives and questions for the Phase I and Phase II Monitoring Plans (Mutch et al. 2005). These questions provide the context as to why we care about forest dynamics, although we may not be able to answer them without more specific research projects aimed at determining the causes for changes we observe from monitoring tree populations. We have not yet determined if we have the resources to monitor in more than one or two forest types, nor have we yet identified varying objectives for more intensively monitored index sites vs. less intensively monitored, more spatially extensive sites. We have identified the highest priority species for long-term monitoring, but analysis of existing data will help inform us about what the cost will be to take a broader (more species) vs. a more focused (one or two species) approach.

Monitoring Questions

- How are the dynamics (establishment, growth and death rates) of tree populations changing in response to changes in climate?
- How do the structure, composition, and distribution of plant communities change in response to variation in climate, fire regime, and human activities?
- How is net primary productivity changing in aquatic and terrestrial systems in relation to changes in climate, fire regime, and human activities?
- How are increasing levels of ozone (and other pollutants) affecting vegetation? Are concomitant changes in fatal insect attacks or tree population dynamics (recruitment and death rates) occurring?

Monitoring Objectives

Species initially identified as highest priority: (1) giant sequoia, (2) sugar pine, and (3) whitebark pine.

Tree population dynamics:

- Determine trends in populations of selected tree species (birth, growth, death rates); growth form, if monitoring whitebark pine
- Monitor trends in causes of tree death
- Monitor trends in white pine blister rust prevalence in five-needle pine populations

Basic Approach

A small work group of USGS and NPS staff members from Sierra Nevada parks and the I&M program was formed to define the monitoring objectives, identify existing datasets that could be resources for power analysis and sample design, determine the approach for protocol development and seek a collaborator for assistance with data analysis and, possibly, protocol development.

At the initial meeting, we prioritized the list of focal species for demographic monitoring that came from the network vital signs workshops (giant sequoia, sugar pine, whitebark pine, ponderosa pine, lodgepole pine, oak woodlands) and narrowed to three species. In order of priority, they were giant sequoia, whitebark pine and sugar pine. Later, we decided we should find a collaborator to analyze existing data to determine sample sizes and sampling intervals needed for detection of trends (such as, 80% chance of detecting 20% change) before we narrow our focus prematurely. A range of alternatives would be investigated (different forest types, different sampling intervals, etc.). This information would then be used to work with a statistician (e.g., Julie Yee of USGS or Leigh Ann Starcevich, Cooperator through the Univ. of Idaho) on a sample design and determine how many forest types and/or species we could monitor.

We identified the following datasets that could be used for analyses:

- Forest demography (most useful)—USGS-BRD (SEKI, YOSE)
- Fire effects—NPS (all parks)
- Lambert/Stohlgren giant sequoia data (SEKI)
- Harvey et al. giant sequoia seedling data (SEKI)
- Giant sequoia tree inventory maps––revisit random areas to determine mortality (SEKI, maybe YOSE)
- White pine blister rust survey data—Duriscoe and USFS (SEKI)

Another task will be to review existing protocols from networks or other agencies (USFS) to determine if there are useful approaches that would meet some of our objectives. The North Coast/Cascades Network (NCCN) forest protocol (Woodward et al. 2009) may have some approaches (sample design, SOPs, database, etc.) that will be helpful to us. The USGS –WERC Sequoia and Kings Canyon Field Station has been doing forest demographic monitoring for many years, and has long-term data, analyses, publications, and approaches that will inform SIEN's protocol development. Finally, the Whitebark Pine Ecosystem Foundation has developed methods for surveying and monitoring whitebark pine stands and blister rust that we will review to determine if their methods will help address our objectives (Tomback et al. 2004).

To address our monitoring objectives, a plot-based approach that tracks individually marked trees will be needed. The following paragraphs are the rationale and considerations for this approach from Nate Stephenson.

The rationale for plot-based monitoring of individually-identified trees is simple. First, the approach gives precise measures of forest composition and structure for change detection. Second, and perhaps more important, it is the only approach that can hope to yield the information needed to develop models capable of forecasting or predicting future changes. Specifically, plot-based monitoring of individually-identified trees yields species-specific demographic rates and growth rates, and sheds light on their controls. Demographic rates determine numbers of trees, while growth rates determine sizes of trees. Together, species-specific numbers and sizes of trees precisely define forest composition and structure. Therefore prediction requires mechanistic understanding of environmental controls of species-specific demographic rates and growth rates.

Experience has proven other ground-based approaches to be less useful. For example, if trees are not individually identified, plot-based approaches effectively become repeated inventories rather than monitoring. Changes in forest structure and composition can still be detected, but all ability to determine demographic rates and growth rates (hence all ability to develop mechanistic models) is lost. Additionally, as empirical data from tropical forests have demonstrated, substantial parallel changes in mortality and recruitment (hence carbon cycling and other aspects of forest function) can occur with little change in forest structure and composition.

Establishment of plot-based monitoring of individually-identified trees is associated with several considerations, as follows.

<u>Tradeoff between plot size and number.</u> A tradeoff exists between precision (having a few large plots that give a precise picture of forest dynamics at a few sites) and accuracy (having more, smaller plots that sample more of the landscape). Experience in both tropical and temperate forests indicates that having more, smaller plots is most useful for addressing the sorts of questions posed here. Experience further indicates that minimum useful plot size often is in the range of 0.5 to 1 ha.

<u>Nested plots.</u> In multi-cohort forests, small trees usually far outnumber large trees. It may therefore sometimes be useful to sample a larger area for large trees than for small trees. However, experience shows that for analysis and interpretation, simplicity of design is quite important.

<u>Minimum tree size sampled.</u> Commonly, the minimum diameter at breast eight (dbh) of trees sampled is 10 cm (especially in exceptionally dense

tropical forests). However, the smallest trees in a forest are usually both the most abundant and most dynamic, meaning that monitoring of smaller trees is critical to derive mechanistic understanding. We recommend monitoring trees of all sizes, including seedlings (see below).

Seedlings. Forests, because they are physically dominated by large trees that live for centuries, are notorious for sometimes having a fair bit of inertia to environmental changes. Seedlings often are more vulnerable to environmental changes than large trees, so that the first signals of environmentally-induced forest change may appear as changes in seedling growth and dynamics. Thus, seedlings should also be monitored, usually in smaller nested plots.

Plot locations. If natural environmental gradients are available (such as elevational or soil fertility gradients), understanding of forest dynamics and change will often advance most quickly if plots are arrayed along the gradients as "natural experiments." *[The NPS I&M program will require that we have a sample design that defines a target population and allocates plots in a random or systematic way to allow inference to that entire population. General Random Tessellation Stratification, or GRTS (Stevens and Olsen 2004), is one approach that I&M networks are using for ensuring spatially balanced sample sites, and we will consider that approach with a statistician as a means of allocating plots across the target areas or populations.]*

Frequency of observation. The most common interval for forest plot monitoring is about five years. Longer intervals tend to create problems, such as tree tags being engulfed by rapidly-growing trees, overwhelming amounts of new recruitment accumulating, and loss of temporal resolution tying forest changes to environmental changes. However, five-year measurement intervals are usually too long to accurately determine probable causes of tree deaths and to confidently link forest changes to certain short-term stresses (like a one- or two-year drought), thereby limiting mechanistic understanding. A strong case can be made for annual monitoring (especially for seedlings), but the extra labor needed usually means that fewer total plots can be monitored.

While plot-based monitoring of individually-identified trees offers the only reasonable means of gaining a mechanistic understanding of forest dynamics (hence predictive ability), by itself it is not sufficient. First, its relatively labor-intensive nature limits it to a tiny fraction of the landscape. Second, it does not adequately measure forest function (though it can provide estimates of aboveground biomass dynamics). Hence, other approaches are also needed.

Other approaches include monitoring of change in forest mosaics at the landscape level using remote sensing and monitoring forest function (carbon exchange between forest systems and atmosphere) using eddy flux towers. The latter is not feasible at this time for the I&M program to pursue due to problems with cost and methodology as well as the "footprint" on the landscape of such structures. To pursue landscape objectives, the forest group will need to work with the landscape group.

We will work with the SIEN Data Manager to develop the data management plan for the protocol, including standard operating procedures for field data collection, database design, data archiving, delivery, and reporting.

Principal Investigators

Current work group members

Lead (2006-2008): Linda Mutch, Network Coordinator

New lead (2009-2010): Shawn McKinney, SIEN Ecologist

Tony Caprio, SEKI Fire Ecologist

Gus Smith, YOSE Fire Ecologist

Nate Stephenson, USGS-WERC Sequoia & Kings Canyon Field Station Research Ecologist

Others who have participated:

MaryBeth Keifer, PWR Fire Ecologist

Adrian Das, Ecologist, USGS-WERC Sequoia & Kings Canyon Field Station

Cooperators

University of Idaho—power analysis and sample design; USGS-WERC Sequoia and Kings Canyon Field Station (data prep for power analysis, protocol oversight and internal review); others—to be determined.

Development Schedule, Budget, and Expected Interim Products

Protocol development was on-hold for several years while staff were working on developing other protocols (wetlands, landscape dynamics).

Table 1: DRAFT forest dynamics protocol development schedule

DATE	DEVELOPMENT
January 2006	Establish draft protocol monitoring objectives and PDS
January 2009	Update PDS to reflect new work group members
May 2009	Re-convene work group and more narrowly define focal forest type for monitoring
Aug–Oct 2009	Assemble datasets for power analysis, do literature review for focal forest types (5-needle pines), and initiate power analyses
Nov 2009–Jan 2010	Do power analyses and develop sample design alternatives to present to Science Committee
Feb–Apr 2010	Draft protocol narrative and SOPs
May 2010	Internal and informal review
Jun–Jul 2010	Field-testing/revision
Aug 2010	Peer review
Summer 2011	Implementation

Table 2. Budget for Protocol Development

PERSON	COST	DESCRIPTION
Shawn McKinney	$40,000	Lead
Linda Mutch, Les Chow	$10,000	Assistance with protocol narrative sections and selected SOPs
Leigh Ann Starcevich—University of Idaho	$15,000	Analyze existing data—power analysis, sample design
Work group members	$10,000	Data compilation, protocol guidance and review, SOP assistance

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Protocol: Lakes

Parks Where Protocol Will be Implemented

Sequoia & Kings Canyon (SEKI) and Yosemite (YOSE)

Vital Signs Addressed by Protocol

Water chemistry
Surface water dynamics
Amphibians

Justification

Sierra Nevada Network (SIEN) parks protect over 4,500 lakes and ponds, numerous other ephemeral waterbodies, and thousands of kilometers of rivers and streams that have some of the highest water quality in the Sierra Nevada. High-elevation lakes are critical components of the parks' ecosystems, popular visitor destinations, and habitat for aquatic and terrestrial organisms including declining amphibian species. Lake ecosystems were selected for monitoring because they are valued for their ecological importance, recreational opportunities, and importance to regional water supplies, are threatened by multiple stressors, and are sensitive to change. Lakes are habitat for three amphibian species that are candidates for listing as endangered under the federal Endangered Species Act—Sierra Nevada and Sierra Madre yellow-legged frogs (*Rana muscosa* and *Rana sierrae*, respectively) and Yosemite toad (*Bufo canorus*).

Background Information

The majority of Sierra Nevada Network lakes are located in the higher elevations (i.e., above 2500 m). Though a few lakes exceed 28 ha, most are only a few hectares in size and vary in depth from less than a meter to over 30 m. Water dynamics in the Sierra Nevada are a critical component of both the parks' ecosystems and the larger California water infrastructure. The snow pack acts as a temporary reservoir, storing water that will be released during the warmer and drier months. Peak runoff typically occurs late May to early June. Water is captured and stored for summer use in a series of reservoirs that line the Sierra foothills. With a few exceptions, reservoirs are primarily located downstream of park boundaries. Primary downstream water uses include irrigated agriculture, domestic water supplies, hydroelectric power, recreation and tourism.

Sierra Nevada lakes are very dilute and characterized as oligotrophic, especially in the sub-alpine and alpine basins where there is sparse vegetative cover, shallow soils, and small contributing area. Despite the low nutrient concentrations, these lakes still support a variety of aquatic fauna including zooplankton assemblages, micro-crustaceans, macro-invertebrates, fish (primarily non-native), and amphibians (Boiano, Weeks et al. 2005). Two amphibian species, mountain yellow-legged frog (*Rana muscosa* and *Rana sierrae*) and Yosemite toad (*Bufo canorus*), are candidates for listing as 'endangered'.

The parks' aquatic ecosystems are subjected to natural and anthropogenic disturbances that have the potential to modify the systems and degrade water resources. Some of the biggest threats to Sierra Nevada lakes are the systemic stressors, which occur at regional and ecosystem scales. These include loss of pre-Euroamerican fire regimes, non-native invasive species, air pollution, habitat fragmentation, and rapid anthropogenic climatic change (SNEP 1996; Sequoia and Kings Canyon National Parks 1999). Aquatic systems are also impacted by localized stressors that threaten relatively small areas or specific water bodies; these include visitor use impacts, small dams and diversions, or abandoned mines.

Water resources are critical components of the parks' ecosystems and indicators of aquatic and terrestrial ecosystem condition. Hydrological and water chemistry measures are good indicators of aquatic and terrestrial ecosystem condition and trend because they reflect changes within the larger watershed. High-elevation lakes of the western United States are especially sensitive to change because the waters are oligotrophic and have a low buffering capacity. Sierra Nevada lakes have some of the lowest acid neutralizing capacity (ANC) concentrations in the western U.S. (Eilers et al. 1989). Changes in nutrient cycles and shifts in phytoplankton communities in Sierra Nevada lakes have been previously detected and attributed to increased nitrogen and phosphorous inputs (Goldman et al. 1993, Sickman et al. 2003).

It is well documented that amphibians are sensitive to ecosystem changes, are easy and relatively inexpensive to monitor, and measures are highly repeatable. Amphibians are sensitive to changes in ecosystem conditions, including: introduction of non-native species and pathogens (i.e., trout, chytrid fungus), habitat fragmentation and degradation (e.g., from pack-stock grazing), water quality (e.g., from toxics such as airborne pesticides), and climate (e.g., global warming, changes in hydrology). The Network would focus on three high elevation anurans: two declining species, namely mountain yellow-legged frog (*Rana muscosa*) and Yosemite toad (*Bufo canorus*); and Pacific treefrog (*Hyla regilla*).

The Network is especially interested in monitoring the Sierran yellow-legged frog (Rana sierrae) and Yosemite toad (Bufo canorus) because of their precipitous decline over the last few decades and potential listing as ‘endangered’ under the Federal Endangered Species Act. The Sierran yellow-legged frog, once the most common vertebrate in the high elevation Sierra Nevada, is a keystone species in high-elevation lakes. They are a major predator of aquatic and terrestrial invertebrates and a food source for alpine predators such as western terrestrial garter snake (*Thamnophis elegans*).

As of 2005, there has been continued decline in mountain yellow-legged frog populations, ranging from 91–98% across the entire range (R. Knapp and V. Vredenberg 2005, unpublished data). Recent research has shown that chytridiomycosis (*Batrachochytrium dendrobatidis*) is a proximate cause of mountain yellow-legged frog mass mortality (Rachowicz et al. 2006). The loss of mountain yellow-legged frogs is likely to have measureable impact on the natural functioning of lakes and streams within their historic range.

The Yosemite toad is endemic to the high Sierra Nevada. It has disappeared from more than 50% of the sites where it was known to occur historically. Overall status for Pacific tree frogs is undetermined, but data suggests decline in certain areas. Although research is still ongoing to fully explain the species’ decline, it is well-documented that introduced fish, which predate on tadpoles, and the disease chytridiomycosis are two of the primary causes. Other evidence suggests that pesticides and climate change may also be contributing factors.

Change detected in high-elevation lakes can be an early warning indication of change that may eventually occur at other elevations and ecosystem types. For example, elevated nitrate concentrations in surface waters are a primary symptom of N-saturated ecosystems (Fenn et al. 1998). Watersheds located near the elevational extremes (e.g., chaparral and alpine) are less effective at retaining nitrogen than mid-elevation ecosystems (Stohlgren 1988; Melack et al. 2002, Fenn et al. 2003). Alpine and sub-alpine watersheds have been shown to have a low capacity to retain nitrogen primarily due to steep talus slopes, shallow soils, and sparse vegetation (Clow and Sueker 2000). Increased nitrogen deposition in the Transverse Ranges of southern California, low elevations in the southern Sierra Nevada, and high-elevations in the Colorado Rocky Mountains has already led to excessive leaching of nitrate into receiving waters (Fenn et al. 2003).

Specific Monitoring Questions and Objectives

Monitoring Questions

The Sierra Nevada Network identified a set of broad monitoring objectives and questions for the Phase I and Phase II Monitoring Plans (Mutch et al. 2005). We used these to guide us in defining the specific monitoring objectives. Lake monitoring, in conjunction with the other indicators, will provide information that will help the network answer these questions. SIEN's broad monitoring questions that pertain to the lake onitoring protocol include:

- How are climatic trends affecting regional hydrologic regimes (snowpack depth, snow water equivalent, snowmelt, glacial extent, frequency and intensity of flood events and volume and timing of river and stream flows)?
- How do depositional patterns of nutrients (principally nitrogen and phosphorus compounds) and other major cations/anions vary along elevation gradients, in aquatic and terrestrial systems, and through time?
- How are patterns of nitrogen cycling changing?
- Are episodic acidification events increasing and are these events altering aquatic communities?
- How are water dynamics changing in response to climate and fire regimes?
- How are surface water volumes changing in lakes and wetlands?
- How does water chemistry (concentrations and fluxes) vary spatially and temporally across network parks?
- How is water quality changing with respect to water quality standards?
- How are plants and animals responding to changes in nutrient concentrations, heavy metals and toxins, sediment loads, and water temperature? What effects are these responses having on aquatic food chains and biological diversity?

Monitoring Objectives

The specific monitoring objectives are divided into three categories: (1) broad spatial scales sites or survey sites, (2) intensive index sites, and (3) landscape.

Survey Sites

- Detect long-term trends in lake water chemistry for Sierra Nevada Network lakes.
  - Temp, pH, sp. conductance, dissolved oxygen, acid neutralizing capacity
  - Major ions: Ca, Na, Mg, K, Cl, SO_4
  - Nitrate, dissolved organic nitrogen, total dissolved nitrogen
  - Total dissolved phosphorus
  - Particulate nitrogen, particulate phosphorus, particulate carbon
- Characterize Sierra Nevada Network lakes.
- Determine the proportion of Sierra Nevada Network lakes above threshold values for selected constituents.
- Detect long-term trends and abundance of high-elevation anurans, particularly mountain yellow-legged frog, Yosemite toad, and Pacific treefrog for Sierra Nevada Network lakes.

Index Sites

- Detect intra- and inter-annual trends in lake water chemistry for Sierra Nevada Network index lakes.
  - Temp, pH, sp. conductance, dissolved oxygen, acid neutralizing capacity
  - Major ions: Ca, Na, Mg, K, Cl, SO4
  - Nitrate, dissolved organic nitrogen, total dissolved nitrogen
  - Particulate nitrogen, phosphorus, carbon
  - Total dissolved phosphorus
- Detect intra- and inter-annual trends in lake level and outflow for Sierra Nevada Network index sites.
- Detect inter-annual trends and abundance of high-elevation anurans, particularly mountain yellow-legged frog, Yosemite toad, and Pacific treefrog for Sierra Nevada Network index sites.

Potential Measures

Water chemistry: pH, dissolved oxygen, specific conductance, temperature, major ions, acid neutralizing capacity, nitrate, dissolved organic nitrogen, total dissolved nitrogen, total dissolved phosphorus, particulate nitrogen, particulate carbon, particulate phosphorus.

Surface-water dynamics: lake outlet discharge lake elevation, lake volume,

Note: timing and duration of ice-out and ice-up may be included as part of the Landscape Dynamics protocol, if possible.

<u>Amphibians:</u> relative anuran abundance (adults, tadpoles, egg masses), species distribution of selected anuran taxa.

Protocol Development & Status

We assembled a small work group, consisting of network and park resources staffs, to identify objectives and outline protocol development strategies for the two water resource vital signs—surface water dynamics and water chemistry. In December 2005, the work group decided that a good strategy would be to separate water resources monitoring into two protocols: (1) Lakes and (2) Rivers and Streams. We will be co-locating amphibian monitoring with the high-elevation lakes monitoring, if feasible. The lake monitoring protocol is being developed in 2006 and 2007. Protocol development for rivers and streams will begin in winter 2007.

The water and amphibian work groups, with input from Drs. James Sickman and David Clow, developed seven primary objectives and one landscape objective. The primary objectives are broken into two groups: (1) extensive sites: low intensity monitoring sites sampled at a broad spatial scale and (2) index sites that will be sampled more intensively.

Field and analytical methods for lake and water sampling are well developed. We will need to determine which methods are best suited for our purposes. We established a Cooperative Ecosystem Unit (CESU) agreement with Dr. James Sickman at the University California, Riverside. Dr. Sickman will be advising us and authoring sections of field and laboratory analytical methods and the Quality Assurance Project Plan (QAPP). The QAPP will be comparable with and meet standards set by the State of California's water quality monitoring program—Surface Water Ambient Monitoring Program (SWAMP). Dr. Sickman will also internally review and provide input on the larger protocol.

The USDA Forest Service has developed a peer-reviewed protocol for mountain yellow-legged frog and Yosemite toad monitoring in adjacent Forest Service lands (Brown 2001). We will use methods from this protocol, with some modifications, for amphibian monitoring in park lakes. This may allow combining of datasets to provide Sierra-wide inference for some species.

Data management components are under development (2007). We are working with the State of California and SWAMP to facilitate information sharing between our programs. We will be using a modified version of the database used by SWAMP. This is an MS Access database consistent with the Natural Resources Database Template (NRDT) with an interface module that will upload data to NPSTORET. The database will also interface with the California Environmental Data Exchange Center (CEDEN) through which all water quality data collected by SWAMP other water quality programs in the state are integrated and made available to the public.

To complement long-term monitoring data, we would like to collect sediment cores for diatom analyses. This would provide information on historical nitrogen loading to SIEN lakes and help us identify threshold conditions. After the core protocol is developed we will be discussing how to best accomplish this component—it is likely we will need to seek additional funding.

Tentative Sampling Methods & Design

A map showing waterbody locations will be provided in the protocol (which is under development). Such map will show the location of index sites, and include the larger "sampled population" (i.e., extensive sites that are part of our sampling frame). Until peer review of the protocol is completed, the generation of random sample sites is premature.

Water chemistry will be measured in Sierra Nevada Network lakes, rivers, and streams. We are currently developing the sample design for lake water chemistry monitoring. We are integrating sampling with surface water dynamics and amphibian vital signs. The approach for river and stream monitoring will not be developed until late 2007-2008.

The Network and others working in large mountainous landscapes have struggled with the trade-offs between in-depth temporal sampling and the ability to make inferences across the landscape. We hope to achieve a balance by applying different sampling frequencies to different sites—survey sites and index sites. We still have many details to consider for a sample design, but an example of the type of design we will likely implement is a spatially-balanced probabilistic design using a rotating panel. Index sites, which will be sampled more frequently, may be selected using criteria such as accessibility, existing monitoring or research, and specific management concerns.

The target population for inference on water chemistry in Sierra Nevada Network lakes includes all lakes in the network that are greater than or equal to 1 hectare in area and greater than or equal to 2 m in depth. Since no lakes occur in Devils Postpile, the target population for the network only includes lakes in Sequoia, Kings Canyon, and Yosemite. The sampling frame will be a GIS coverage from the National Hydrography Dataset which enumerates all lakes within the park. Unequal inclusion probabilities may be formed based on a cost surface model.. Inference at the park and network level is desired, so if budgets allow, the survey design may treat the parks as strata so that inference at the park level is possible. The sampling unit for this survey will be lakes.

Surveys will be conducted to obtain estimates of status and trend. Status measurements will include measures of lake characteristics and the proportion of lakes above a certain threshold value (to be determined). Trends of chemical concentrations and ratios of constituents are also of interest. Because status is of interest and trend at the landscape level, random samples will be selected using a GRTS design to ensure spatial coverage of lakes within parks. A rotating panel design may be used so that trend may be estimated over time. Tradeoffs between replication in space at a given time for status and replication over time for trend will be explored.

Index sites will be used to monitor sites of particular interest, based on existing research and monitoring, accessibility or demonstrated sensitivity to certain stressors.. These index sites will be visited more frequently, for instance once or twice a month, from spring through fall. Additional instrumentation will be used at index sites so that continuous data collection is possible.

A wealth of data is available for sample size approximation and power analysis. Fall lake chemistry data is available from the EPA's 1985 Western Lake Survey (Eilers et al. 1987) and a 1999 resurvey (Clow et al. 2003). The Seven Lakes Study data set has approximately five years of chemistry and flow data for seven lakes in and near network parks. Over 20 years of data are available from research and monitoring conducted at Emerald Lake. Ultimately, managers need temporal data over a broader spatial scale for trend analysis at a wider scale.

Amphibians

SIEN's science committee has decided that fiscal and logistical limitations necessitate the exploration of integration of amphibian monitoring with lake chemistry monitoring. We do not know if this will meet our amphibian monitoring or sampling objectives. We are also working with our statistician to see if–and at what level–integration can be achieved. Most lake measures will be collected in the late summer into fall; this precludes some amphibian sampling, as tadpoles and adults may be less abundant and detectable (e.g., *Hyla*). However, we have not yet conducted data analyses to assess the practicality of integration. For example, if feasible we will include lakes with a history of long-term amphibian monitoring in the lake index sites, which will be sampled throughout the season.

Our current target population includes populations (historic and extant) of mountain yellow-legged frog (*Rana muscosa*), Yosemite toad (*Bufo canorus*); and Pacific treefrog (*Hyla regilla*) in SEKI and YOSE. Decisions for sampling amphibians in DEPO have not been made; only one of our target species (Pacific treefrog) occurs there.

Details regarding sample design and probability of inclusion for amphibian populations have not been worked out yet: discussions continue between the two workgroups at this time. Detailed GIS coverages encompassing a wealth of recent amphibian data exist for both SEKI and YOSE. Large and extensive GIS coverages and datasets are available for amphibians, both from the parks themselves (e.g., comprehensive inventories; ten+ years of data at one site in Yosemite), and from surrounding USFS long-term monitoring. Under a best-case scenario, amphibian measures (e.g., abundance of anurans) would be collected at both index and extensive sampling sites, for park-level inference on trends and abundance.

The USFS within the Sierra Nevada has developed a GRTS-based, peer-reviewed monitoring protocol for mountain yellow-legged frogs and Yosemite toads that has implemented over the past five years across all Sierra Nevada national forest lands (Brown 2001). Full collaboration between NPS and USFS would be cost-effective, and would provide a complete regional picture of the status and population trends of these declining amphibians across lands with varying management practices; however, current level of SIEN monitoring funds preclude such collaboration. Regardless, we are working with our statistician to explore opportunities for data sharing with USFS.

Principal Investigators

The Sierra Nevada Network Physical Scientist will coordinate and complete the Lake protocol development with significant contributions and guidance from the Sierra Nevada Network Water Resources Work Group, National Park Service-Water Resources Division, and cooperators.

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Development Schedule, Budget, and Expected Interim Products

The Sierra Nevada Network initiated development of the lake monitoring protocol in December of 2005 (Table 2). The protocol will be submitted for peer-review in fall 2007. In FY06, $10,000 were allocated to University California, Riverside (Dr. Sickman) for assistance with analytical methods and internal review of the larger protocol. In FY07, $19,000 was allocated for database modifications and training. Additional resources included statistical consulting (costs shared with other vital signs), time from park staff (from park base funds), time from the network Data Manager, and significant time from the Network Physical Scientist.

Table 3: Lake Protocol development schedule

DATE	DEVELOPMENT
December 2005	Identify objectives and approach
2006-2007	Develop protocol
Fall 2007	Submit for peer-review
Summer 2008	Implement

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Protocol: Landscape Dynamics

Parks where protocol will be implemented

Yosemite (YOSE)
Sequoia & Kings Canyon (SEKI)
Devils Postpile (DEPO)

Vital Signs Addressed by Protocol

Landscape mosaics
Fire regime
Snow cover
Phenology
Forest patch dynamics

Justification

Remote sensing of land use patterns offers a relatively rapid and cost effective method to assess large and small spatial scale changes in the landscape.

There are a variety of major factors threatening the integrity of Sierra Nevada ecosystems. Regional science has identified climate change (anthropogenic), altered fire regimes, non-native invasive species, air pollution, and habitat fragmentation as the five primary threats to Sierran systems (SNEP 1996). With a rapidly expanding human population and a steeply rising projection in the state's population size, these threats are likely to only increase in scope and severity. In particular, the Sierra Nevada foothills are projected to be heavily impacted by future development. Climate change is also predicted to play an increasingly important and serious role in California, posing a significant threat to the existence and persistence of native ecosystems and species (California Energy Commission 2003; Hayhoe et al. 2004). Decades of fire suppression and predicted climate shifts are likely to bring dramatically altered fire dynamics to the Sierra Nevada.

Background Information

Remote sensing has been used for almost two decades to assist in answering a variety of ecological and landscape questions and issues. These include land cover classification, ecosystem function, change detection, and monitoring process such as flooding and disease spread (Kerr and Ostrovsky 2003; Ager and Owens 2004). Land cover and its spatial patterns are key aspects of ecological monitoring. Landscape patterns and the patchwork of vegetation communities integrate biotic and abiotic factors in their structure and composition. Thus, remote sensing can detect changes in both the land cover type and in the variability of particular land cover types (such as vegetation). Although not the canary-in-a-coalmine, changes in plant community health, composition, extent, and spatial arrangement as well as changes in snow cover and timing can reflect changes in climate, biotic interactions, fire regimes, or anthropogenic forces.

There are two primary justifications for wanting to monitor the change in landscape dynamics (including fire) over time:

1. To document the change where and when it occurs. This information can then be applied to respond to crises or to direct managers to areas of heightened concern. Remote sensing provides techniques and data to allow for the preparation of scientific responses to environmental change.
2. To use data to build models of predicted future landscape mosaic patterns. This will allow managers to prepare for and then manage for ecosystem changes that are likely to affect processes, systems, and individual species.

Fire has played a pivotal role in shaping ecosystems and landscapes in the Sierra Nevada for many millennia (Davis and Moratto 1988; Smith and Anderson 1992; SNEP 1996; Anderson and Smith 1997). It affects numerous aspects of ecosystem dynamics such as soil and nutrient cycling, decomposition, succession, vegetation structure and composition, biodiversity, insect outbreaks, and hydrology (Kilgore 1973, SNEP 1996).

From the late 1890s through 1960s, Sierra Nevada park and national forest personnel attempted to suppress all fires, and these efforts met with a fair degree of success. Consequently, numerous ecosystems that had evolved with frequent fires have since experienced prolonged periods without fire (Swetnam et al. 1992; Swetnam 1993; Caprio and Graber 2000; Caprio et al. 2002; Caprio and Lineback 2002). In 1968 (Sequoia & Kings Canyon) and 1970 (Yosemite), NPS staff began prescribed burning. After more than 30 years of prescribed fires, significant progress has been made, though park efforts are far from restoring natural fire regimes at the landscape level (e.g., (Caprio and Graber 2000; National Park Service 2004).

Climate change and associated predicted changes in fire extent, severity, and occurrence are expected to be the primary drivers of landscape change in the Sierra Nevada in the foreseeable future. The altered fire regimes that have resulted from fire exclusion are currently considered one of the most important stressors on our natural systems. Therefore, it is imperative that we document and understand how climate change will affect fire regimes which will in turn to help interpret changes in plant community composition, structure and function; water chemistry and dynamics; and animal populations' abundance and distribution.

Attributes of pre-Euroamerican fire regimes can provide vital reference information for understanding changes in ecosystems over the last 150 years and in developing goals for the restoration of fire. The concept of a fire regime allows us to view fire as a multi-faceted variable rather than a single event within an ecosystem (Whelan 1995). Thus, areas can be classified as having a certain type of regime that summarizes the characteristics of fires, within some range of variability that can have both spatial and temporal attributes. Fire regimes are normally defined according to specific variables including frequency, magnitude (intensity, severity), size, season, spatial distribution and type of fire (Gill 1975; Heinselman 1981). These fire regime characteristics can vary through time and across the landscape in response to climatic variation, number of lightning ignitions, topography, vegetation, specific historic events and human cultural practices (SNEP 1996).

The National Parks of the Sierra Nevada (Yosemite, Kings Canyon, Sequoia, and Devils Postpile) together have established a large proportion of the central and southern Sierra Nevada as federally protected areas. Together they help to protect one of the nation's and the world's most biotically unique and diverse locations. Consistently, the California Floristic Province (of which the Sierra Nevada is a part) is identified as a global biodiversity hotspot (Meyers et al. 2000; Whittaker 2005) where large concentrations of endemic species are threatened by loss of, or degradation of habitat. In accordance with this level of global biodiversity, resource managers of the Sierra Nevada Network parks must use any and all methods available to document and assess impacts to these federal protected lands. Information can be collected from the ground or remotely using satellites or aircraft. Remote sensing of land use patterns offers a relatively rapid and cost effective method to assess large and small spatial scale changes in the landscape.

Specific Monitoring Questions & Objectives

The Sierra Nevada Network (SIEN) has a landscape protocol work group that identified the following primary onitoring objectives:

1. Determine how vegetation type and cover is changing over time. Use remote sensing data and technology to detect changes in vegetation type and cover from a baseline on a 5-10 year interval.
2. As often as necessary, use remote sensing to detect the extent and severity of fire events and incorporate these into change detection maps. This detection will occur in every year there is at least one fire of significant size (to be determined).
3. Determine how snow cover within the parks is changing both inter-annually and intra-annually. The objective is to monitor how snow cover duration may be changing over time and how it is changing within the season (e.g., detect if timing of the initiation or melt of snow cover is changing over time.). This will be monitored on a 2-5 year interval.
4. Determine probable causation of changes detected in vegetation type and cover based on pilot studies of

past disturbance events including fire and insect damage.

5. Determine changes in the distribution and abundance of vegetation and land cover classes over time. Metrics of patterns including total area, number of patches, mean patch size, mean inter-patch distance, and overall patch class diversity will be used to characterize and track changes in landscape dynamics.
6. Determine changes in vegetation health or condition over time. Various remote sensing derived metrics of vegetation health can be used to monitor how vegetation health may be changing. These include Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI), Fraction of Photosynthetically Active Radiation (FPAR), and Leaf Area Index (LAI), and possibly others. These metrics can be used in conjunction with the normally derived vegetation type and cover change detection to monitor vegetation condition. This will be monitored on a 2-5 year interval.
7. Using the change detection analysis, determine how vegetation phenology is changing over time. Phenology can include leafout, leaf senescence, and vegetation growth or activity (as detected with metrics such as NDVI). The objective is to determine how vegetation types are responding to changes in climate and other disturbances (i.e., is growing season expanding?).

In addition to the seven objectives outlined above, we would like to explore the potential of using remote sensing to help monitor other aspects of the landscape. These secondary objectives would assist in the monitoring of other "vital signs" that are or will be slated for long term monitoring in the SIEN.

These secondary objectives will have the advantage of extensive field validation data that will be collected as part of the monitoring effort of the other vital signs. These data will be valuable for informing change detection analysis.

Secondary objectives include:

8. Use finer scale remotely sensed imagery (e.g., 5-10m) monitor the changes in forest patch dynamics over time. This would focus on a few important vegetation classes or communities dominated by significant species. The objective would be to monitor how overall cover and patch dynamics (e.g., total cover, mean size, inter-patch distance) is changing.
9. Use remote sensing to monitor the presence and spread of a small number of non-native plant species. This would require fine resolution imagery (1-5m).
10. Monitor changes in the extent and number of meadows as well as their vegetation composition and health. This would require finer resolution imagery as many meadows are small (< 100m across). The desire is to monitor how meadows may be shrinking or disappearing across the landscape, and how the vegetation community may be changing.
11. Monitor how the timing of ice-over and ice-out of lakes is changing inter-annually in response to climate change. This also would require fine resolution imagery (1-5m) as many lakes are also small.

Basic Approach

The protocol objectives, above, were developed by two separate work groups, both comprised of NPS and USGS staff members: a landscape dynamics workgroup and a fire regimes workgroup. Objectives were developed and prioritized for these two vital signs separately, and in October 2006, the two groups met together to merge the objectives from the groups into one protocol. From this date on, we plan to proceed with one protocol development approach.

A cooperative agreement with the Oregon State University has been established (FY 2007-2008) to assess SIEN's landscape monitoring objectives in relation to appropriate remote sensing technologies and methods and existing relevant datasets, to determine which objectives can feasibly be pursued given anticipated resources, and to test and develop a protocol that meets local needs for landscape change monitoring. This will include providing alternatives for acquiring the expertise needed to process and interpret remote-sensing imagery.

Protocol Development & Status

SIEN and cooperators at OSU will conduct a workshop during FY2008 with the Sierra Nevada Network's "landscape work group", other interested stakeholders in the parks, and National Aeronautics and Space Laboratory, Ames Research Center (NASA-Ames) collaborators to provide an overview of approaches developed or in-progress for other networks, to frame SIEN monitoring objectives in the context of remote sensing approaches, and to determine which objectives are the most feasible to pursue with available resources.

Phase 1 of this project will rely on transfer of existing tools and related protocols developed for the North Coast and Cascades Network (NCCN) and Southwest Alaska Network (SWAN) from the cooperators to the SIEN. These tools have been (and continue to be) developed and tested at other western park networks and should be readily transferable to the SIEN (after a set of pilot studies). Both draft and final protocols based on these existing tools will be developed for the SIEN as a part of this phase. Existing protocols developed for NCCN and SWAN will likely not meet all of the SIEN remote sensing monitoring objectives. Therefore, Phase 1 will also involve, as a set of additional pilot studies, development of new tools to more fully address the complete set of SIEN remote sensing monitoring objectives. A report describing these new tools and their potential for addressing the fuller set of SIEN remote sensing monitoring needs will be provided.

Phase 2 of this project will include an additional period of technology transfer, in which cooperator time will be devoted to helping SIEN personnel implement the protocols developed during Phase 1 of this project. If additional funds are available, Phase 2 will also involve further development and testing of (and writing of protocols for) the fuller set of remote sensing monitoring tools tested and reported on in Phase 1. Attachment I further describes the project and contains a more detailed study plan.

Tentative Sampling Methods & Design

Our goals will require monitoring the landscape on varying time scales, depending upon the question asked. For longer term questions such as changes to overall landscape patterns, we will take the approach of monitoring landscape dynamics on a longer term time scale (5-10 years). This basic landscape dynamics monitoring will involve a comparative spectral analysis between imagery from time 1 and time 2. Only those areas that are identified as having a significant spectral change will be remapped. The most appropriate imagery is likely to be Landsat Thematic Mapper (TM) at a resolution of 30 meters. This imagery should be available free of cost to the National Park Service.

Once areas that have experienced spectral change are identified, either ground truthing and/or use of high resolution aerial photography will be used to verify those changes. This methodology has been used for a variety of applications with success (e.g., Oetter et al., 2000). Depending upon availability and cost, digital orthophotoquads (DOQQs) may also be used at this step. Field work conducted through other protocols (such as Forest Dynamics) may be used to verify spectral changes identified in the analysis. One possibility is to use the inventory of the Forest Inventory Assessment plots that are maintained and periodically monitored by the US Forest Service. A final step of the process will be to assign causality to the identified change, if possible.

There are two approaches that could be pursued in the process of change detection. One would be to conduct a detection of change in the patterns of the landscape within the parks will be based upon existing base maps such as recent vegetation maps. All four vegetation maps are highly detailed and should be sufficient for use as a base map. Once landscape changes are identified, the vegetation base map would then be updated as necessary. The other approach would be to map change only based on spectral differences between time one and time two TM imagery.

This is the method chosen by the North Coast/Cascades Network (NCCN). This method is not tied to an original base map and so this may present some difficulties with translating the spectral changes to the physical reality of what exists on the landscape. It is likely that we will apply the first approach.

In addition to an analysis of landscape change, we want to analyze changes in the mosaics of landscape units. This will involve an analysis of the landscape patterns that characterize the composition, extent, and spatial arrangement of land cover and vegetation units. Metrics will allow us to analytically measure change within the landscape. Metrics of spatial pattern can be generated using a combination of analysis ool in ESRI's ArcGIS and others such as FRAGSTATS. These metrics will include:

1. Composition (the variety and abundance of distinct patch types)
   a) Proportional abundance of each type
   b) Richness: total number of patch types
   c) Evenness: the relative abundance of different patch types
   d) Diversity: a composite of richness and evenness (e.g., Shannon Weaver)
2. Spatial Configuration
   a) Patch characteristics (size shape): mean, max, variance
   b) Spatial relationships: nearest neighbor, clustering, dispersion, connectivity
   c) Contrast: differences among patch types
   d) Corridors

We will want to focus a considerable amount of the effort on monitoring changes in metrics of forest/vegetation health over time, in conjunction with the change detection analysis (every 5-10 years). Metrics derived from the TM imagery such as NDVI, FPAR, and LAI can be calculated to detect alterations in the health and/or composition of the vegetation.

Currently, Sequoia, Kings Canyon, and Yosemite have existing fire management programs that new fire extent annually and calculate fire return interval and have recently begun to determine fire severity within the boundaries of burn areas using Landsat imagery. Efforts of this protocol will aim to complement, not duplicate, the fire monitoring program within the parks. The Sierra Nevada Network, with its Science Committee and protocol work groups, will need to determine whether it has the resources to enhance and build upon existing fire regime monitoring efforts in Sierra Nevada parks, or whether it will need to limit its role to synthesizing and helping make more available already existing data.

Some of our objectives will require the purchase of imagery with a much finer scale (less than 5m). Questions such as meadow health and extent, timing of lake ice-out, phenological timing, and invasive plants extent will require finer scale imagery. This imagery does come with a greater cost and the monitoring objective will have to be prioritized if and when funds are not sufficient to answer all questions. This fine scale imagery may cost thousands to tens of thousands of dollars for the four SIEN parks as imagery may need to be purchased for several times throughout the year. A complete cost-benefit analysis would need to be written to help in protocol objective prioritization.

Other protocols to be implemented within the Sierra Nevada Network also have identified a potential need for remote sensing to assist is achieving their goals. These include monitoring extent and health of meadows, detecting and monitoring invasions by non-native plants, and forest condition and patch dynamics. Although the parks currently have a program to monitor the annual extents and timing of fires, additional remote sensing analyses can assist to monitoring vegetation change following fire.

Many of the details of the change detection methods will be taken from the NCCN vegetation monitoring protocols. The US Forest Service and the California Department of Forestry and Fire Protection (CDF) have also instituted a change detection program for forests in the Sierra Nevada that is tailored to detecting changes to the cover of conifer and hardwood forests over time (Fisher et al., 2004) but does not take a broader look at landscape mosaic patterns and dynamics. The landscape mosaics protocol will be implemented to complement the USFS and CDF change detection program and to take advantage of their output.

Principal Investigator, NPS Lead, Workgroup Members, and Collaborators

This protocol development will be accomplished by cooperators at Oregon State University and NASA-Ames in collaboration with Sierra Nevada Network scientists, both within the NPS and the USGS.

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NASA Ames Research Center

DEVELOPMENT SCHEDULE, BUDGET AND EXPECTED INTERIM PRODUCTS	
Finalize protocol objectives and PDS	Fall 2006
Task Agreement with OSU	Summer 2007
Workshop with work group and cooperators	Fall 2007
Workshop report and Study Plan	Winter 2008
Draft protocol SOPs complete	August 2009
Draft protocol narrative complete	August 2009
Protocol finalized for peer review	January 2010

BUDGET	
FISCAL YEAR 2006	Landscape Ecologist for 2 pp (one to I&M) @ $2634/pp = $5268
FISCAL YEAR 2007	Protocol development task agreement (PNW CESU, Oregon State University~ $100,000
	YOSE Landscape Ecologist Bill Kuhn for 3 pp -- $8,300
FISCAL YEAR 2008	YOSE Landscape Ecologist Bill Kuhn for 4 pp $11,500
	Other costs associated with protocol completion- TBD
	Imagery costs—TBD

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Protocol: Wetlands Ecological Integrity

Park Where Protocol will be Implemented

Yosemite National Park (YOSE)
Devils Postpile National Monument (DEPO)
Sequoia and Kings Canyon National Parks (SEKI)

Vital Signs Addressed by Protocol

Wetland water dynamics
Wetland plant communities
Macro-invertebrates (wetland)

Justification

Wetlands[1] (often referred to as "meadows" in the Sierra Nevada) are diverse and complex ecosystems that vary widely in character and composition, though occupying only a small fraction of the land surface of the Sierra Nevada (Benedict and Major 1982; Ratliff 1982; Kaczynski 2007). Wetlands form in catchments where soils are saturated or flooded for at least a portion of the year. Wetlands occur in basins, on slopes, along streams, and adjacent to lakes and ponds. Sierra Nevada meadows range in size from small patches to large expanses, such as Tuolumne Meadow in Yosemite National Park. Most Sierra Nevada wetlands occur above snowline, where snowmelt provides moisture during the summer growing season. In addition to surface flow, moisture enters wetlands from streams and from sub-surface flows that are forced to the surface by local geomorphology. Wetlands have varying levels of moisture, both temporally and spatially, reflecting the relative availability of water during the summer growing season.

Background Information

Sierra Nevada wetland vegetation is dominated by perennial graminoids, which reflect the relatively short growing season of the middle and high elevations. Key genera include *Carex*, *Deschampsia, Calamagrostis, Juncus, Danthonia*, and *Eleocharis*, with species composition of individual wetlands determined by local moisture regime and soil characteristics. Annual productivity of wetland graminoids is closely tied to the amount and timing of winter snows as well as changes in length of growing season associated with such fluctuation; when late lying snows shorten the growing season, productivity declines accordingly. In some wetlands with higher moisture availability,, mosses are also important, forming mats and hummocks under favorable conditions. Woody plants are generally excluded from wetlands because of seasonally saturated soils. However, willows (*Salix* spp.) are frequently found along stream channels and often form patches within wetlands. Lodgepole pine, *Pinus contorta*, with a high tolerance for saturated soils, is commonly encountered in and adjacent to wetlands. Lodgepole pine take hold during dry years and give way to wetland vegetation under wetter conditions in a dynamic cycle of invasion and retreat.

Wetlands provide critical breeding and foraging habitat for a suite of animal species. Recent work by (Holmquist and Schmidt-Gengenbach 2005; Holmquist and Schmidt-Gengenbach 2006) in the Sierra Nevada parks demonstrated the importance of wetlands as breeding grounds for invertebrates, which form the energetic basis of many food chains. Many insects breed in wet meadows, then disperse into adjacent forests and woodlands as the season progresses (Holmquist and Schmidt-Gengenbach 2005). Wetland invertebrates also serve as pollinators for montane and high elevation plants. A number of bird species, such as the rare willow flycatcher, use wetlands for foraging, nesting, or both. Mule deer take advantage of the cover provided by

1 For purposes of this protocol, wetlands included are primarily palustirne emergent wetlands, and may include extensive areas of palustrine scrub-shrub (primarily willows, Salix sp.), and/or palustrine forested (primarily lodgepole pine, *Pinus contorta*, or aspen, *Populus tremuloides*)—wetland taxonomy of Cowardin et al (1979). Using terminology defined in Mitsch and Gosselink (1993, page 32), these wetlands consist primarily of wet meadows, but also include fens, marshes, and small patches of swamp. Marshes associated with the edge of lakes and ponds are excluded from this protocol, but the protocol includes riparian areas within wetlands.

montane wetland vegetation by hiding their fawns in dense vegetation. Small mammals, such as ground squirrels, pocket gophers, and voles feed on meadow vegetation, and play a significant role in soil perturbation. Animals such as frogs, toads, and shrews frequent the moist vegetation and stream channels.

As wetlands, wet meadows provide important ecological and cultural functions. Some of the functions described by Mitsch and Gosselink (1993) and Williams (1990) that might apply of the Sierra Network meadows include: (1) influencing regional water-flow regimes including flood mitigation by intercepting and slowing the release of water to streams, (2) improving water quality by removing nutrients and toxic materials, (3) sediment trapping, (4) sources for some of the highest productivity in the world, (5) important habitat for wildlife, and (6) aesthetic values to the people that visit them. Peat-accumulating wetlands in their natural condition remove and store carbon. If altered, such as by drainage, the process would reverse contributing to atmospheric carbon dioxide through oxidation (Gorham 1991). Wetlands play an important role in the nitrogen and sulfur cycles. In the anaerobic reducing environments of wetland soils, nitrogen in nitrate, ammonia, and organic nitrogen is returned to the atmosphere as N2, and sulfur is converted to hydrogen sulfide (Gosselink and Maltby 1990; Mitsch and Gosselink 1993). This helps mitigate some of the nutrient deposition from air pollution. Wet meadows provide unique intersection of terrestrial and aquatic, aerobic and anaerobic conditions.

Wetlands are susceptible to the same stressors that affect the Sierra Nevada parks as a whole. Climate change has the potential to shift the species composition of mountain meadows through changes in the timing and amount of snowmelt and subsequent alteration of the underlying hydrology of local systems. Experimental manipulations in the Rocky Mountains demonstrate that increased temperatures can lead to a general drying down of mountain wetlands, subsequent invasion by woody species such as sagebrush, influence carbon fluxes (Saleska et al. 1999), and cause shifts in timing of flowering of wetland species (Dunne et al. 2003).

Although Sierra Nevada high elevation weltands have so far proven to be relatively resistant to invasion by non-native plants (Gerlach 2004), wetlands in the lower montane are demonstrably susceptible to invasion by the non-native Kentucky blue grass (*Poa pratensis*), which now dominates some heavily grazed wetlands in Sequoia and Kings Canyon National Parks (Neuman 1990; Gerlach et al. 2003; Gerlach et al. 2004). Dandelion (*Taraxacum officinale*), a common invader of mountain wetlands worldwide, is also frequently encountered in disturbed wetlands and riparian areas of the Sierra, especially in those that are heavily grazed.

Serious invasive invertebrates have not been reported in any of the wetlands of Sierra Nevada parks yet, but invertebrate research in these meadows is in its infancy. The New Zealand mud snail, *Potamopygrus antipodarum*, occurs both east and west of the Sierra Nevada parks, and could easily become established in meadow streams, transported on the boots or waders of anglers or perhaps as hikers back-flush their water filters. As the climate warms, Argentine ants, *Linepithema humile*, could invade wetlands, displacing native ants and altering ecosystem processes like seed dispersal and plant pollination. One introduced species, an earwig from Europe, *Forficula auricularia*, has been collected in the meadow at Devils Postpile National Monument (Holmquist pers. com.).

The parks' receive considerable input from agricultural pesticides (Cory et al. 1970; Zabik and Seiber 1993; Aston and Sieber 1997; Datta et al. 1998a; Datta et al. 1998b; McConnell et al. 1998; McConnell et al. 1999; LeNoir et al. 1999; Angerman et al. 2002) A growing body of scientific evidence suggests that the pesticides may be impacting wetland amphibians (Sparling et al. 2001; Fellers et al. 2004). Further, there exists an inverse relationship between pesticide use and downwind occurrence of frog populations (Davidson 2004). Pesticides, herbicides, and other contaminants could also be impacting invertebrate populations (Curry 1994; Cilgi and Jepson 1995; Scholtz and Kruger 1995; Longley and Sotherton 1997; Clay and Riedell 1998; Ellsbury et al. 1998; Stewart 1998), especially at the higher trophic levels.

Several new diseases could alter native vertebrate populations within wetlands as well as other park habitats. A recently emerging pathogenic fungus, *Batrachochytrium dendrobatidis*, which causes chytridiomycosis, has reached Sierra Nevada aquatic environments, including the wet meadows and marshes. The disease has caused widespread decimation of the mountain yellow-legged frog, *Rana muscosa*. The genetic data suggests that *B. dendrobatidis* is new to the area (Rachowicz et al. 2005). West Nile virus has reached the Sierra Nevada, and the recently discovered avian-adapted influenza A subtype H5N1 is anticipated to reach the western hemisphere soon. These diseases have potential to alter meadow bird populations in and around meadows and interrupt ecosystem processes in which birds play a role.

Nitrogen pollution from atmospheric deposition has the potential to affect productivity of wetland vegetation, and depending on seasonal timing, may affect aquatic organisms such as algae and invertebrates.

Although fire can impact wetlands directly when vegetation is dry enough to burn, such events do not appear to lead to long-term changes (DeBenedetti and Parsons 1984). More long-lasting impacts are seen when stand-removing fires in adjacent forests are followed by increased flooding and surface erosion. This can lead to the deposition of sands and gravels during storm events and thus return the wetland vegetation to an earlier successional stage. This process can be important to the establishment of willows (Argus per. com.). Fire has also been shown to alter ant assemblage structure in fens (Ratchford et al. 2005). Fire can also maintain wetland edges (Norman and Taylor 2005).

Wetland invertebrates are especially sensitive to fragmentation by trail corridors, with declines in species abundance and diversity observed as much as 2 m away from trail treads in seemingly undisturbed vegetation (Holmquist and Schmidt-Gengenbach 2004). As a result, broad scale impacts can be exacerbated by local disturbances.

During the mid-1800s and into the early 1900s, most Sierra Nevada wetlands were grazed, in some cases severely, by cattle and sheep. Many park wetlands continue to be grazed by recreational and administrative pack stock, and this activity has a suite of known impacts to meadows such as soil compaction, erosion, trampling of vegetation, and changes in plant species composition (Ratliff 1985; Stohlgren, DeBenedetti et al. 1989; McClaran and Cole 1993; McClaren and Cole 1993; Moore et al. 2000). Recent research in Yosemite National Park suggests that even moderate levels of such grazing can have a measurable effect on wetland productivity (Cole et al. 2004).Though the sample size was small, Holmquist (unpublished data) found differences among invertebrate communities between grazed and ungrazed wetlands in the Rock Creek area of Sequoia National Park. Elsewhere, studies have shown that grazing of grasslands affects small mammals (Grant et al. 1982; Keesing 1998; Matlack et al. 2001) and ground-nesting birds (Dobkin et al. 1998; Pavel 2004).

Specific Monitoring Questions and Objectives Addressed by the Protocol

Monitoring questions

1. Are hydrologic processes (e.g., duration, depth, timing of surface and groundwater) in wetlands changing?
2. Is the structure of wetland vegetation (e.g., composition, plant species abundance, standing crop, ground cover) changing?
3. Is the composition, abundance, or trophic structure of aquatic or terrestrial invertebrate communities changing in wetland ecosystems?
4. Are introduced species (plants,

invertebrates, vertebrates) expanding or declining in wetlands?

5. Are observed changes in flora and/or fauna correlated with changes in hydrologic patterns?
6. Do observed changes in geomorphic processes correlate with changes in flora and fauna?
7. Is wetland condition changing as reflected in changes in hydrology, vegetation, fauna and/or overall biodiversity or productivity?
8. Is human use visually altering Sierra Nevada wetlands?

Monitoring Objectives

1. Determine temporal changes in species composition and abundance of wetland vascular and non-vascular flora, including changes in exposed bare ground.
2. Determine temporal changes in the composition and relative abundance of above-ground wetland invertebrate populations at the level of Family (Order when necessary for efficiency) except for identifying ants to species.
3. Determine temporal changes in hydrology including the duration, depth, and timing of surface and ground water.
4. Document temporal changes in coarse measures of anthropogenic influences to wetlands.

For each of the objectives, the protocols will be designed to detect at least a 20 percent decadal change with 80 percent power. These numbers may change somewhat after power analyses are completed.

Potential Measures

<u>Wetland water dynamics</u>: duration, depth, timing of surface and ground water,ground water pH and electrical conductance, water chemistry, stream condition (if present), soil compaction, evidence of recent depositional events into the meadow, evidence of small mammals.

<u>Wetland plant communities:</u> presence/absence, rate of spread for taxa not being managed,frequency, abundance and distribution of native plants in relation to changes in the same measures for non-native plants in selected communities, native & non-native species ratios and non-native species abundance in selected communities.

<u>Macroinvertebrates:</u> community composition of wetland macro-invertebrates, distribution and relative abundance of wetland macro-invertebrates.

See, also, discussion of measures in more detail below (Protocol Development & Status).

Protocol Development & Status

The field protocol is being tested in Yosemite National Park (summer 2007): wells and plots are being installed (N=60 sites), including several (N=6) index (sentinel) sites. A full complement of data are being collected for the following vital signs: hydrology (surface and groundwater dynamics), wetland plant communities, and invertebrates. Depending on the number of sites installed in summer 2007and assessment of data in power analyses, site installation will continue in Yosemite and Sequoia & Kings Canyon (summer 2008).

The Sierra Network (SIEN) wetlands ecological integrity protocol will emphasize the measurement of vascular and non-vascular floristic composition, invertebrate populations, and hydrology to document wetland condition and change. The hydrology drives the natural ecology of the wetlands systems and serves as a covariate for interpreting other wetlands measures. Vegetation provides the productivity, physical structure, and wildlife habitat (along with water) for the wetland community. Vascular and non-vascular vegetation facilitates water quality maintenance, supports a wide variety of fauna, and provides long-term response to environmental change. Wetlands invertebrates are the predominant in terms of abundance and species richness) wetlands fauna and provide a rapid response to environmental change caused by various stressors. Invertebrates include representatives of several trophic levels and are important food resources and processors of organic material, represent a crossroads for ecological flows (e.g., aquatic-terrestrial), are easy to sample quantitatively, and are sensitive to a variety of stresses and in turn are capable vectors for cascading disturbances (Holmquist and Schmidt-Gengenbach 2004).

The work will utilize two complementary and integrated types of monitoring sites: (1) extensive, randomly selected long-term monitoring sites, and (2) more temporally intensive measures at judgment-selected sites that will provide more complete information and serve as index sites for the extensive sampling. The first type will allow valid statements of condition and long-term trend at the network scale. The index sites will track shorter term dynamics, link to existing long term monitoring and potentially allow more explicit interpretation of the network-scale information. The index sites could also become the focal points for related research projects.

Tentative Sampling Methods & Design

The target population for inference on wetlands ecological integrity includes approximately 12,000 wetlands in SEKI and YOSE; only a single wetland complex occurs in DEPO.The general approach for selecting wetlands for monitoring will be as follows. First a watershed classification will be developed using the GIS layers that collectively characterize the diversity of SIEN watersheds, especially with regard to the watersheds' potential influence on meadow development and ecology. Spatial data to form the basis for the classification may include maps of bedrock geology, extent of Pleistocene glaciation, and climate (or a surrogate for climate). We will use the selected spatial data to determine the proportion of each watershed that has distinctive surficial geology, glaciated vs. non-glaciated areas, and the primary source of precipitation (e.g., snowmelt dominated, snowmelt and rain dominated, or primarily rain dominated).

The data for each watershed will be analyzed using cluster analysis, and a watershed classification would be developed based upon physical characteristics that are known to influence the abundance and types of wetlands occurring (Winters et al. 2003). A second tier of watershed classification might include stressor predictors (e.g., distance from the Central Valley, drainage orientation (rain shadow effects), grazing intensity, backpacker density, etc). The cluster analysis will be used to identify major types (estimate 6-8) of watersheds in SIEN. We will then randomly choose two or three watersheds of each type for wetland analysis using a two-stage GRTS design.

Within randomly-selected watersheds, we will use the wetlands on the National Wetlands Inventory (NWI) maps using the classification of Cowardin, et al. (1979) as a starting point. In the southern Sierra Nevada, only two thirds of the NWI sites are correctly classified as palustrine emergent (meadows), but most of the errors were palustrine scrub-shrub (willows; Werner 2004). The scrub-shrub wetlands may be of interest to this monitoring. Additional accuracy will be achieved utilizing Network vegetation maps. The classification of SIEN wetlands will resemble the classification present in Carsey et al. (2003), which is based upon principles of the hydrogeomorphic (HGM) approach to wetland analysis (Brinson 1993), and an HGM classification by Cooper (1998). Wetlands in NWI maps, as well as the Inventory and Monitoring Program vegetation mapping data, will be reanalyzed using natural color aerial photographs, and each wetland polygon will be preliminarily classified as riparian, marsh, wet meadow or fen. This monitoring effort will focus on wet meadows and fens, and may include marshes, meadow riparian areas, palustrine scrub-shrub and palustrine forests associated with each site. The classification will provide a means of subdividing wetlands that occur in SIEN parks into a few major types that can be mapped within randomly selected watersheds. We would then randomly choose two or three wetland complexes of each type in each watershed (the second stage of the GRTS design) for monitoring.

At each wetland complex selected for long term monitoring, aerial photographs, and field inspection of the site will be used to refine the map of the major wetland types and communities occurring at each site. In many mountain environments, several wetland types (e.g., fens, wet meadows and riparian areas) can occur within the same wetland polygon, and may be fed by different water sources. Each will have distinctive hydrologic regimes, vegetation, and wetland functions. Within each wetland site, the major communities will be identified and sampling site(s) selected. An unbiased design or mechanism will be developed for selecting these final sites within each community type. Index sites will receive one or more ground water monitoring wells. At extensive sites, only water table measurements will be taken. The location for vegetation and invertebrate sampling will be based on the ground water measurement locations and will stay within the community represented by the water table measurements.

Extensive sites will be visited annually, each summer, based on hydrologic cycle. Index sites will be used to monitor sites of particular interest—chosen based on accessibility, history of research at the site, ability to install instrumentation because site is not subject to Wilderness Act concerns, etc.. Survey seasons and scope are limited by spring snow, stream crossings, weather, and so on. Survey site protocols will follow established methods for assessing vegetation composition and structure along with the necessary supporting habitat information (especially ground water dynamics, select soil and water physiochemistry, and habitat structure).

Index site protocols will include all survey site methods, plus additional continuous monitoring of ground water dynamics and water physiochemistry, again using established methodology. Index sites will be visited more frequently, from mid-May through October. These sites will be used to estimate inter-annual variability (e.g., vertebrates).

Both quadrat and transect data are available to inform plot sample size approximation and power analysis of wetland vegetation. We have several years of invertebrate data from our work supporting development of this monitoring protocol. Our existing data provide a baseline for variability of a site; we have some data to inform spatial variability. We may have some well and vegetation data to inform power to detect trend.

Principal Investigators and NPS Lead

Protocol development, field monitoring implementation and data analysis will be done collaboratively through a cooperative agreement with Colorado State University and with the University of California, White Mountain Research Station.

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Development Schedule, Budget,

and Expected Interim Products

Planning for protocol development is in progress. Decisions regarding the final design should occur during a field trip during the week of July 24 in Yosemite National Park or shortly thereafter. Preparation of the draft protocol SOPs is targeted to begin September 11, 2006 with review completed by December 11, 2006. The draft SOPs will be implemented during the summer of 2007 with an evaluation completed by October 1, 2007. The SOP for data management will be prepared during the fall and winter of 2007-2008 and before March 30, 2008. Preparation of the protocol narrative and revision of SOPs is targeted for April 28, 2008. The final draft will be applied during the summer of 2008. Following evaluation of the 2008 field season during September 2008, the draft protocol will be fine-tuned and targeted for completion by May 2009. External costs are expected to be about $10,250 in FY06, $51,346 in FY07, and $41,484 in FY08 ($103,080 total) for the vegetation and hydrology components and an additional $24,704 in FY06, $43,410 in FY07, and $43,410 in FY08 ($111,524 total) for the invertebrate components.

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Protocol: Rivers and Streams

Parks Where Protocol Will be Implemented

Devils Postpile National Monument (DEPO)
Sequoia and Kings Canyon National Parks (SEKI)
Yosemite National Park (YOSE)

Vital Signs Addressed by Protocol

Water chemistry
Surface-water dynamics

Justification

Water quantity and quality are critical components of the parks' ecosystems and indicators of aquatic and terrestrial ecosystem condition. Hydrological and water quality parameters are good indicators for detecting ecological change because they reflect changes within the larger watershed. Ecological changes following a disturbance (natural or anthropogenic) may occur locally in the area affected or may be detected downstream. Changes may be detected immediately following one disturbance or may not be detected until multiple disturbances have occurred. Therefore, analyzing water quality parameters at different spatial and temporal scales can be a useful tool in detecting change at the watershed scale.

Background Information

Sierra Nevada Network (SIEN) parks protect over 4,500 lakes and thousands of kilometers of rivers and streams that have some of the highest water quality in the Sierra Nevada. The parks' ecosystems are subjected to natural and anthropogenic disturbances that have the potential to modify the systems and degrade water resources. Managers and researchers, using the findings from the Sierra Nevada Ecosystem Project (SNEP 1996), identified five important systemic stressors to Sierra Nevada systems: (1) loss of pre-Euroamerican fire regimes, (2) non-native invasive species, (3) air pollution, (4) habitat fragmentation, and (5) rapid anthropogenic climatic change (Sequoia and Kings Canyon National Parks 1999). The stressors with the greatest impact on the parks' flow regimes and water quality are altered fire regimes, air pollution, and climate change. Park aquatic ecosystems are also susceptible to localized stressors which include visitor use impacts, small dams and diversions, park infrastructure (i.e., sewage treatment plants, roads), and abandoned mines.

Over 100 years of fire suppression polices have altered fire regimes in the Sierra Nevada Network parks. Potential effects on water resources from a lack of fire are reduced stream flows, changes in biogeochemical cycling and decreased nutrient inputs to aquatic systems (Chorover et al. 1994; Williams and Melack 1997; Hauer and Spencer 1998; Moore 2000). Less frequent but higher severity wildfires have the potential to impair water resources by increasing flooding, erosion, sediment input, water temperatures, and nutrient and metal concentrations (Tiedemann et al. 1978; Helvey 1980; Riggan et al. 1994; Mac Donald and Stednick 2003).

High elevation lakes and streams in the Sierra Nevada are oligotrophic, have a low buffering capacity, and sensitive to change from atmospheric deposition of nutrients, toxic substances, and acids (Goldman et al. 1993; Leydecker et al. 1999; Davidson and Shaffer 2002; Sickman et al. 2003).

It has been predicted that even a modest temperature increase (2.5 °C) from global climate change will significantly alter hydrologic processes. The most pronounced changes are earlier snowmelt runoff, reduced summer base flows and soil moisture, (Dettinger et al. 2004), a lower snowpack volume at mid-elevations (Knowles and Cayan 2001), and increased flooding, including rain-on-snow events. The water infrastructure in California was built under the assumption that the Sierra Nevada snowpack would act as a temporary reservoir for the State's water and release it slowly during the spring and early summer months. Changes in precipitation type and timing will result in longer and drier summers with less water available for ecosystems and regional economic uses during the months it is most needed. Water quality would be threatened by increased flooding and erosion and lower summer flows.

Specific Monitoring Questions and Objectives

We will identify specific river and stream monitoring objectives in fall 2009.

Basic Approach

We assembled a small work group, consisting of network and park resources staffs, to determine objectives and outline protocol development strategies for the two water resource vital signs—surface water dynamics and water chemistry. In December 2005, the work group decided that a good strategy would be to separate water resources monitoring into two protocols: (1) Lakes and (2) Rivers and Streams. The Lake monitoring protocol is under-development; the final protocol will be ready for peer review in spring 2008. The Rivers and Streams protocol development will begin in fall 2009. We have few details for this protocol development summary because our staff is focusing on the lake monitoring protocol this year.

Protocol Development & Status

Will begin late 2009.

Potential Measures

Streams and Rivers

pH, dissolved oxygen, specific conductance, temperature, major ions, acid neutralizing capacity, nitrate, dissolved organic nitrogen, total dissolved nitrogen, total dissolved phosphorus, particulate nitrogen, particulate carbon, particulate phosphorus, stream discharge (peak flow/low flow/water yield), qualitative estimate of flow relative to bank full.

Tentative Sampling Methods & Design

Will be determined by the Sierra Nevada Network Water Resources Work Group (late 2007–2008).

Principal Investigators

The protocol development strategy and cooperators will be determined by the Sierra Nevada Network Water Resources Work Group in 2007.

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Development Schedule, Budget, and Expected Interim Products

The stream protocol development will begin in fall 2009. The water resources work group will determine the specific monitoring objectives, development strategy, and timeline at that time. The protocol is tentatively scheduled to be ready for peer-review in fall/winter 2010.

Table 3: Rivers and Streams Protocol development schedule

DATE	DEVELOPMENT
Fall 2009	Begin protocol development
Fall/Winter 2010	Submit for peer-review
Summer 2011	Implement protocol

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Parks Where Protocol Will be Implemented

Devils Postpile National Monument (DEPO)
Sequoia & Kings Canyon (SEKI)
Yosemite National Parks (YOSE)

Vital Signs Addressed By Protocol

Weather
Climate
Snowpack

Justification

Climatic forces are a major driver of Sierra Nevada ecosystems. Current patterns of vegetation, water dynamics, and animal distribution in the Sierra are determined largely by cumulative effects of past and present climates. Not surprisingly, anthropogenic climate change is the stressor that is predicted to have the most pronounced effects on Sierra Nevada ecosystems. Weather and climate was one of the top ranked vital signs for our network. The primary reasons the Sierra Nevada Network selected weather and climate are (1) changes in local and regional climate patterns will cause change in park ecosystems and resources of concern; (2) weather data will be used to explain patterns observed in other indicators (i.e., surface water dynamics, meadows, birds); and (3) partnership and cost leveraging opportunities with other agencies and universities.

Background Information

The last several decades in the Sierra Nevada were among the warmest of the last millennium (Graumlich 1993). Paleoecological records show the early and middle Holocene (ca. 10,000 to 4,500 years ago) was a period of generally higher global summer temperatures (perhaps by 2° C) and prolonged summer drought in California. During this period, fire regimes and vegetation community composition of Sierra Nevada forests differed from those of today (including some species combinations that no longer exist) (Anderson 1990; Anderson and Smith 1991; Anderson 1994; Anderson and Smith 1994; Anderson and Smith 1997).

Human-influenced temperature patterns are significantly associated with discernible changes in plant and animal phenological traits (Root et al. 2005). Global warming is likely to shift habitats to higher elevations. Some organisms with limited mobility or specific habitat needs (e.g., amphibians) may not be able to move or survive such habitat shifts and could be locally extirpated. Consequently, species diversity may decline. Some habitats (e.g., high alpine) may shrink dramatically or disappear entirely, leading to irreversible loss of some species (e.g., Clark's Nutcracker)

It has been predicted that even a relatively modest mean temperature increase (2.5 °C) would significantly alter hydrologic processes. The most pronounced changes would probably be earlier snowmelt runoff, reduced summer base flows and soil moisture (Dettinger et al. 2004; Dettinger 2005), a lower snowpack volume at mid-elevations (Knowles and Cayan 2001), and increased winter and spring flooding (Dettinger et al. 2004). High spring run-off flows in many western streams begin a week to almost three weeks earlier than they did in the mid 20th century (Cayan et al. 2001; Dettinger 2005). Glacial extent in the Sierra Nevada has declined markedly in the past several decades (Basagic 2008). If the current trends continue, the "natural reservoirs" provided by snowpack will become progressively less useful for water resources management, flood risk may change in unpredictable ways, and Sierra Nevada ecosystems will experience increasingly severe summer-drought conditions (Dettinger 2005; Dettinger et al. 2005; Mote et al. 2005).

Global climate change is also likely to exacerbate three other systemic stressors: altered fire regime, air pollution, and non-native species. Some models predict future climate change will be accompanied by increased lightning strikes at latitudes spanned by the Sierra Nevada (Price and Rind 1991). Compounding the increase in wildfire ignitions, extreme weather conditions such as drought are likely to result in fires burning larger areas, being more severe, and escaping containment more frequently (Torn and Fried 1992; Miller and Urban 1999). Warm temperatures create the perfect conditions for the production of "smog," or ground-level ozone. Global warming is therefore likely to make air pollution problems (e.g., ozone) worse. A warmer climate would allow certain species—for example, those species unable to get a stronghold because of cold temperatures—to thrive and reproduce.

Specific Monitoring Questions and Objectives

We will identify specific monitoring objectives in fall 2007. In the interim, we have identified project-oriented objectives for both weather inventory and monitoring that we ill focus on in the next year:

1. Assist Dr. Kelly Redmond and Western Regional Climate Center (WRCC) staff with the weather station inventory
2. Assess current climate monitoring, which includes identifying data gaps and determining 'high priority' sites for the parks and vital signs monitoring. Determine if we want to add instrumentation to existing sites, make data more available or real-time, or assist with maintaining of sites. Assess need for and feasibility of adding new stations in the parks
3. Develop protocol and Standard Operating Procedures for the Devils Postpile new meteorological station. These will be incorporated into the larger climate monitoring protocol
4. Develop an interpretive sign for the new Devils Postpile meteorological station
5. Determine the role that I&M will have in analyses, summaries, reporting, and delivery of meteorological data
6. Coordinate micro-scale weather monitoring across vital signs, depending on the needs of other work groups (e.g., if several protocols include collecting parameters such as air temp and RH at their plots, lakes, etc., then the type of equipment and protocols should be consistent.)

Potential measures

<u>Weather and climate:</u> precipitation, temperature, wind speed, wind direction, solar radiation, relative humidity, soil moisture, soil temperature.

<u>Snowpack:</u> snow depth, snow cover, snow water equivalent, timing of snowmelt.

Basic Approach

The first climate monitoring project that the network was involved in was the installation of a new meteorological station in Devils Postpile National Monument. The monument had no current weather monitoring. The purchasing, installation, and management of the station were a cooperative effort between the Sierra Nevada Network, California Department of Water Resources-Cooperative Snow Surveys, Scripps Institute of Oceanography, and US Geological Survey.

The climate work group will focus on the above six objects over the next year. Overviews of how these individual objectives will be accomplished are as follows:

1. Andi Heard (SIEN physical scientist), with input from park and USGS staff, will assist the Western Regional Climate Center with the weather inventory project. This will involve providing information on weather station metadata as requested by WRCC.
2. Assessing Network climate monitoring needs and objectives will be accomplished through a Cooperative Ecosystem Unit (CESU) agreement with Dr. Kelly Redmond at WRCC. This agreement began in October 2006.
3. The protocol and Standard Operating Procedures for the Devils Postpile meteorological station are being primarily developed by Dr. Daniel Cayan (Scripps/USGS) and student Martha Coakley (UC San Diego) with contributions from Frank Gehrke (Calif. Cooperative Snow Surveys) and Douglas Alden (Scripps). Annie Esperanza and Andi Heard are the NPS contacts and are also contributing content to the protocol.
4. Deanna Dulen and staff will take the lead on developing an interpretive sign for the meteorological station. The exhibit will be installed in 2007.

5. Defining I&M's role in climate monitoring will be ongoing. The current projects, particularly the climate assessment project, will inform this process.
6. As needed, the climate work group will provide support to other work groups for small scale (i.e., plots, lakes) weather monitoring.

Protocol Development & Status

Although, the above-mentioned projects will feed into the climate monitoring protocol, most of the protocol development will not begin until sometime in 2007, when he climate work group will identify specific monitoring objectives and a detailed protocol development strategy. Meteorological monitoring in the parks is currently conducted by several divisions within the National Park Service and multiple outside agencies. The work group will be working with cooperators to best determine how the Inventory and Monitoring Program can contribute to the existing meteorological monitoring infrastructure. We will be looking for opportunities to collaborate with other agencies in the short-term to develop the protocol and for the long-term to continue meteorological monitoring in the parks.

Tentative Sampling Methods & Design

Unlike most other vital signs, various measures of SIEN park climate have been monitored for the last century. Currently, an existing network of monitoring stations is maintained by a variety of state and federal agencies and universities within and adjacent to the parks. Most existing sites were selected using best professional judgment of that time; changes to existing sites would severely compromise existing legacy climate data from these stations. Our basic approach involves a detailed analysis of existing climate monitoring stations to determine whether they provide adequate sampling of spatial and temporal variability and adequate data for strata of management interest or scientific importance. We will use the results of this analysis to determine how the Network can best contribute to the current system.

Specific monitoring objectives and protocol development strategy will be determined by the Sierra Nevada Network Climate Work Group.

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Development Schedule, Budget, and Expected Interim Products

In 2006 and 2007, several projects were initiated that will directly inform the Weather and Climate monitoring protocol. These include the weather inventory, climate monitoring assessment, and Devils Postpile weather station protocol development projects. In summer/fall 2009, we will determine the strategy and timeline for fully developing the protocol. In FY2005, the network put $20,000 towards the purchase and installation of a new meteorological station at Devils Postpile. In FY06, $32,000 were put towards climate related projects, including the Climate Monitoring

Assessment agreement with the Western Regional Climate Center, an interpretive exhibit for the new Devils Postpile meteorological station, and SOP development for the Devils Postpile station (Table H-5).

Table 2: Weather and Climate Protocol development schedule

DATE	DEVELOPMENT
Spring 2006 – Winter 2007	DEPO protocol development
Summer 2007	Weather inventory complete
October 2007–September 2008	Climate monitoring assessment
August 2009–May 2010	Protocol development
June 2010	Protocol peer review

Table : Budget for FY06 and FY07 Climate Projects

WHAT?	WHO?	AMOUNT
Climate Assessment	WRCC	$24,000
Wayside Exhibits	DEPO	$3,150
DEPO Protocol	Scripps	$4,000

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